

CITY OF THUNDER BAY
DRINKING WATER SUPPLIES

ELEVATED LEAD LEVELS

NOVEMBER, 1975



Ministry
of the
Environment

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ONTARIO MINISTRY OF ENVIRONMENT

SPECIAL INVESTIGATION

CITY OF THUNDER BAY - DRINKING WATER SUPPLIES

ELEVATED LEAD LEVELS

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SUMMARY

Lead levels higher than the Ontario standard of 0.05 mg/l were discovered in the Thunder Bay South Ward water supply early in 1975. Subsequent testing by the Ministry of the Environment indicated that the elevated levels existed because chemically aggressive water from Loch Lomond reacted with lead service connections from the municipal system to residences.

Although elevated lead levels were also detected in the North Ward water supply from Lake Superior, the concentrations were normally below the permissible limit because the water has a greater buffering capacity and hence a lower lead uptake rate than the Loch Lomond water.

Since the installation of the water distribution system in 1906, there has been no clinical indications of lead poisoning reported. Therefore, the lead levels in the water may not pose a serious health hazard.

Studies revealed that chemical treatment to increase the alkalinity of the water would reduce the lead uptake rate and should minimize other corrosion problems.

Several methods to solve the problem of high lead levels in the water have been proposed but this Ministry recommends that the City provide for chemical treatment of Loch Lomond water to increase the alkalinity and thus reduce its aggressiveness.

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INTRODUCTION

The City of Thunder Bay has two municipally operated water works systems. The North Ward obtains water from Lake Superior while the South Ward receives water by gravity from Loch Lomond. The raw waters from these lakes are chlorinated prior to distribution to the community. The water demands from the two systems are approximately equal and average 8 million gallons per day. The water distribution system in many areas of the City was installed in 1906 when lead service connections were commonly employed to transport water from water mains to residences. The lead service pipes were generally $\frac{1}{2}$ inch in diameter and approximately 60 feet in length.

It has been known for years that the South Ward water is chemically more aggressive than the North Ward water.

The problem of elevated lead levels in the water was not noticed until recently when the City received complaints from one of its residents regarding foreign material in his water supply.

A water sample from this residence (1413 Moodie Street), in the South Ward, was found to contain a considerable amount of brown flakes. An analysis of the sample revealed a total lead level of 1.9 mg/l. This level was in excess of the level generally recognized as the maximum permissible in the Province, 0.05 mg/l.

Based on these findings a study was undertaken by the Ministry of the Environment to determine the nature and extent of the problem of elevated lead levels for the two City water supplies.

The study was divided into two phases. Phase I study identified the extent and causes of the elevated lead levels and Phase II study explored: the variation of the lead levels in the water, hot water tanks as another potential source of lead, and the possible solutions to the problem.

After the completion of the Phase I study, the City of Thunder Bay and the Thunder Bay District Health Unit began to conduct independent studies. Since their undertakings were relevant to this study, summaries of their findings and conclusions are also included in this report as two separate sections.

PHASE I STUDY BY MINISTRY OF THE ENVIRONMENT

This study was designed to determine the general magnitude of the lead levels in the water and their causes. The investigation first concentrated on the area where lead was first found in the water and then was extended to both the South and North Wards covering both lead and copper service connections. Lead levels in the water supply were also determined prior to the water being exposed to the service connections.

Phase I Results and Discussion

Elevated lead levels were first discovered in the area of Moodie Street and these levels are shown in Table I.

The concentrations were higher than the permissible limit. Samples from 1413 Moodie Street often contained some brown particulate material. Table II shows the chemical composition of the particulates found in a sample having 0.18 mg/l of dissolved lead.

On February 7, 1975, Municipal staff sampled various residences and a hospital in the same general area where lead was first discovered. On February 11, 1975 these samples were repeated where possible. The results are summarized in Table III. The two sets of results are in close agreement. Additionally, it was shown that houses with lead service connections had elevated lead levels in their water but the hospital and residences with copper connections had lead levels much lower than the maximum permissible of 0.05 mg/l as did the Loch Lomond supply.

TABLE I

Lead Levels in Water Samples from Residences on Moodie Street (January 29, 1975).

House Number	Total Lead Concentration (mg/l)
1411	0.12
1413	0.33*
1417	0.11

* Sample contained brown particulate material.

TABLE II

Analysis of Water Samples from 1413 Moodie Street (February 6, 1975).

Sample	Concentration	% Composition
Filtered Water	0.18 mg/l lead	
Particulate		20% as copper 19% as lead 14% as iron 0.1% as zinc Remainder - oxides and carbonate

TABLE III

LEAD CONCENTRATION IN WATER FROM THE SOUTH WARD

Location	Total Lead Concentration (mg/l)	
	Feb. 7/75	Feb. 11/75
1411 Moodie St.	0.067	0.057
1412 Moodie St.	0.021	0.015
1413 Moodie St. (cold)	0.082	0.077
	-	0.130 **
1413 Moodie St. (hot)	0.140	-
1417 Moodie St.	0.075	0.074
616 Franklin St.	0.032	0.024
459 Empire Ave.	0.028	0.026
1428 Isabella St.	0.019	0.016
1503 Walsh St.	0.078	0.068
613 Norah St.	-	0.050
614 Norah St.	0.032	-
1400 Murray Ave.	0.041	0.034
1413 Hamilton Ave.	0.041	0.038
* McKellar Hospital	0.006	-
* 1817 Moodie Street	-	<0.004
* 138 Meryle Street	-	<0.004
Loch Lomond (treated)	<0.004	-

* Copper service connection

** Contained particulate material

Based on these preliminary findings a more comprehensive study was carried out in both the North and South Wards of the City. The study consisted of examining four residential blocks, two of which were located in the North Ward and two in the South Ward. In each Ward, one block was known to be serviced by copper pipe connections and one block by lead pipe connections. Samples were collected from the kitchen taps in each case and analysed for their lead content.

In addition to the above, samples were taken from the street mains to establish the lead levels prior to passing through the house connection.

The sampling results are presented in Tables IV, V, and VI.

The North Ward water in those houses served by lead connections contained concentrations of lead ranging from 0.008 to 0.050 mg/l with an average of 0.026 mg/l. A total of 20 samples were obtained on this block. None of the levels exceeded the 0.05 mg/l maximum concentration.

The block in the North Ward served by copper services had lead concentrations ranging from 0.004 to 0.019 mg/l with an average of 0.007 mg/l, all well below the maximum permissible of 0.05 mg/l.

In the South Ward those houses served by copper service connections had lead levels ranging from 0.004 to 0.009 mg/l with an average concentration of 0.006 mg/l, well below the permissible limit.

TABLE IV

Lead Levels in North Ward Residences with Lead and
Copper Connections

Lead Connections February 25, 1975 Peter Street		Copper Connections February 20, 1975 Penfold Street	
House No.	Lead (mg/l)	House No.	Lead (mg/l)
11	0.018	67	0.005
18	0.050	72	0.006
28	0.044	73	0.006
29	0.022	76	0.019
31	0.020	80	0.004
56	0.014	84	0.005
58	0.026	85	0.007
59	0.008	89	0.006
66	0.049	92	0.004
72	0.008	108	0.008
79	0.023	109	0.010
80	0.032	120	0.005
86	0.034	124	0.011
100	0.026	128	0.007
103	0.028	131	0.006
105	0.028	132	0.006
107	0.020	135	0.005
108	0.022	139	0.005
109	0.028	140	0.007
113	0.010		

TABLE V

Lead Levels in South Ward Residences with Lead and Copper Connections

<u>Lead Connections</u> February 19, 1975 N. Brodie Street		<u>Copper Connections</u> February 17, 1975 W. Christina Street	
<u>House No.</u>	<u>Lead (mg/l)</u>	<u>House No.</u>	<u>Lead (mg/l)</u>
305	0.035	210	0.008
307	0.064	214	0.004
310	0.110	223	0.009
311	0.027	226	< 0.004
312	0.063	227	0.004
313	0.080	230	0.007
314	0.076	237	0.005
316	0.120	244	0.006
317	0.063	245	0.006
318	0.120	248	< 0.004
319	0.110	249	< 0.008
320	0.100	255	< 0.004
330	0.098	258	0.004
335	0.062	261	0.006
337	0.078	264	0.009
343	0.059	265	0.004
345	0.072	270	0.006
351	0.063	274	0.006
357	0.140	275	0.004
367	0.068	307	< 0.004

TABLE VI

Lead Levels in Water from Street Mains

<u>Location</u>	<u>Lead (mg/l)</u>
Heath and Christina	0.012
Peter at Dawson	0.006
Peter at Hebert	0.006
Penfold at Huron	0.007
Penfold at Clayte	0.006
Brodie at Cumming	0.013
Brodie at Cameron	0.007

The block in the South Ward served by lead service connections had lead levels ranging from 0.027 to 0.14 mg/l with an average of 0.080 mg/l. Of the 20 samples analysed, 18 were above the permissible maximum limit.

The water samples taken from the street mains had lead concentrations ranging from 0.006 to 0.013 mg/l, well below the maximum permissible.

These results again illustrated that elevated lead levels were associated with lead service connections for both South and North Wards of the City. Furthermore, the lead concentrations in the South Ward residences were generally much higher (about 3 times) than those in the North Ward.

STUDY BY CITY OF THUNDER BAY

The City engaged a consulting firm to investigate treatment of the South Ward water supply. The consulting firm has recently completed a preliminary investigation on the chemical treatment required to reduce lead levels and other corrosion problems. An addition of 30 mg/l of calcium carbonate and 8 mg/l of lime to the South Ward water was recommended to reduce its aggressiveness.

The total estimated operating and capital cost was \$38,000 a year.

The City has also completed an examination of its records to determine the extent of lead service connections in the City and has estimated that the total cost required to replace the 5,300 lead connections in the South Ward is about \$2,000,000.

STUDY BY THUNDER BAY DISTRICT HEALTH UNIT

The Medical Officer of Health arranged for the testing of lead levels in blood of children under five years of age. This age group was selected as it is generally recognized as the one being most susceptible to elevated lead levels. As there has been no clinical evidence of lead being a problem in the City to date, the programme was limited to the examination of blood samples from children already being subjected to blood testing.

A total of 51 children were tested over a six week period. Eleven of them were from households with lead connections. It was found that there was no significant difference between the group from households with lead and those without lead connections. The majority of results were well below 20 ug/100 ml, where 40 - 80 ug/100 ml is the level at which minimal lead intoxication problems may start to appear. Therefore, the Medical Officer of Health concluded that there was no health hazard from lead in the water supply. A report on the study has been submitted to the City by the Medical Officer of Health.

PHASE II STUDY BY MINISTRY OF THE ENVIRONMENT

Three additional investigations were undertaken by the Ministry of the Environment. First, houses known to have lead service connections were examined to determine how lead concentrations would vary in the water supply subsequent to the supply not being used for a period of time. Samples were obtained at numerous intervals for approximately 2 hours subsequent to the supply being out of action. The non-use period chosen was overnight.

The second study involved the examination of hot water tanks, both in service and one taken out of service, to determine if scale and sediment in the tanks might represent a source of lead that would result in higher lead levels in the water supply due to increased solubility at the elevated temperatures.

The final study was conducted by the Ministry regional laboratory personnel to determine the effectiveness of chemically treating the water supply to reduce its aggressiveness and hence the lead uptake rate.

Phase II Results and Discussion

The three investigations conducted in this Phase II study will be discussed separately along with their results.

(1) Variation of Lead Levels in Water

A total of four sets of samples were collected from three residences in the morning when the water taps were first used after an overnight shut-off.

All samples were taken from the kitchen taps of each house, and the water was allowed to run at a controlled rate of approximately 0.5 gallon per minute for the duration of the test. In one set, the samples were collected over the same period of time but the water was turned off between each sample interval.

The results are summarized in Table VII and graphically presented in Figure 1. The lead concentrations varied with the resident times of the water in the lead service connections but levelled off at some constant value for the three tests which allowed the water to run continuously. In all cases, the initial concentrations were in excess of the permissible limit, including the samples from the North Ward residence.

However, once the service connection had had a sufficient volume of water through it to flush the line from the street to the house, the level of lead dropped significantly. Even the set of samples (Line 4 in Figure 1) taken over a period of time, where no flow was allowed between sample interval, showed a decrease in lead concentration until the shut-down interval started to exceed 10 minutes. Lead is constantly dissolving into the water at such a rate that, with the tap running continuously, a constant level of 0.07 mg/l is observed in one case as shown by line (3) in Figure 1. If the water is allowed to flow only for the time period that the sample is being obtained, the lead will begin to accumulate in the water left standing in the pipe at a rate of

TABLE VII

Lead Levels versus Time Elapsed Since Tap Turned on

Time Elapsed	Lead Concentration (mg/l)			
	(1) *	(2)	(3)	(4)
0 Secs.	0.13	0.084	0.36	0.40
30 Secs.	0.080	0.076	0.58	0.51
1 Min.	0.017	0.084	0.64	0.64
2 Mins.	0.016	0.094	0.21	0.55
3 Mins.	0.014	0.061	0.13	0.29
4 Mins.	0.017	0.034	0.088	0.14
5 Mins.	0.014	0.033	0.089	0.13
10 Mins.	0.016	0.033	0.078	0.13
20 Mins.	0.017	0.026	0.071	0.17
30 Mins.	0.016	0.033	0.070	0.21
1 Hr.	0.014	0.034		0.26
1.5 Hrs.	0.017	0.034		0.29
2 Hrs.	0.014	0.034		0.35

- * (1) North Ward; 3 Bare Point Road; March 19, 1975; 8:00 a.m.
Tap water turned on during test period.
- (2) South Ward, 464 E. Brock Street; March 10, 1975; 8:15 a.m.
Tap water turned on during test period.
- (3) South Ward, 436 S. Norah Street; March 6, 1975, 7:00 a.m.
Tap water turned on during test period.
- (4) As (3); March 4, 1975; 7:00 a.m.
Tap water turned off between each sample interval.

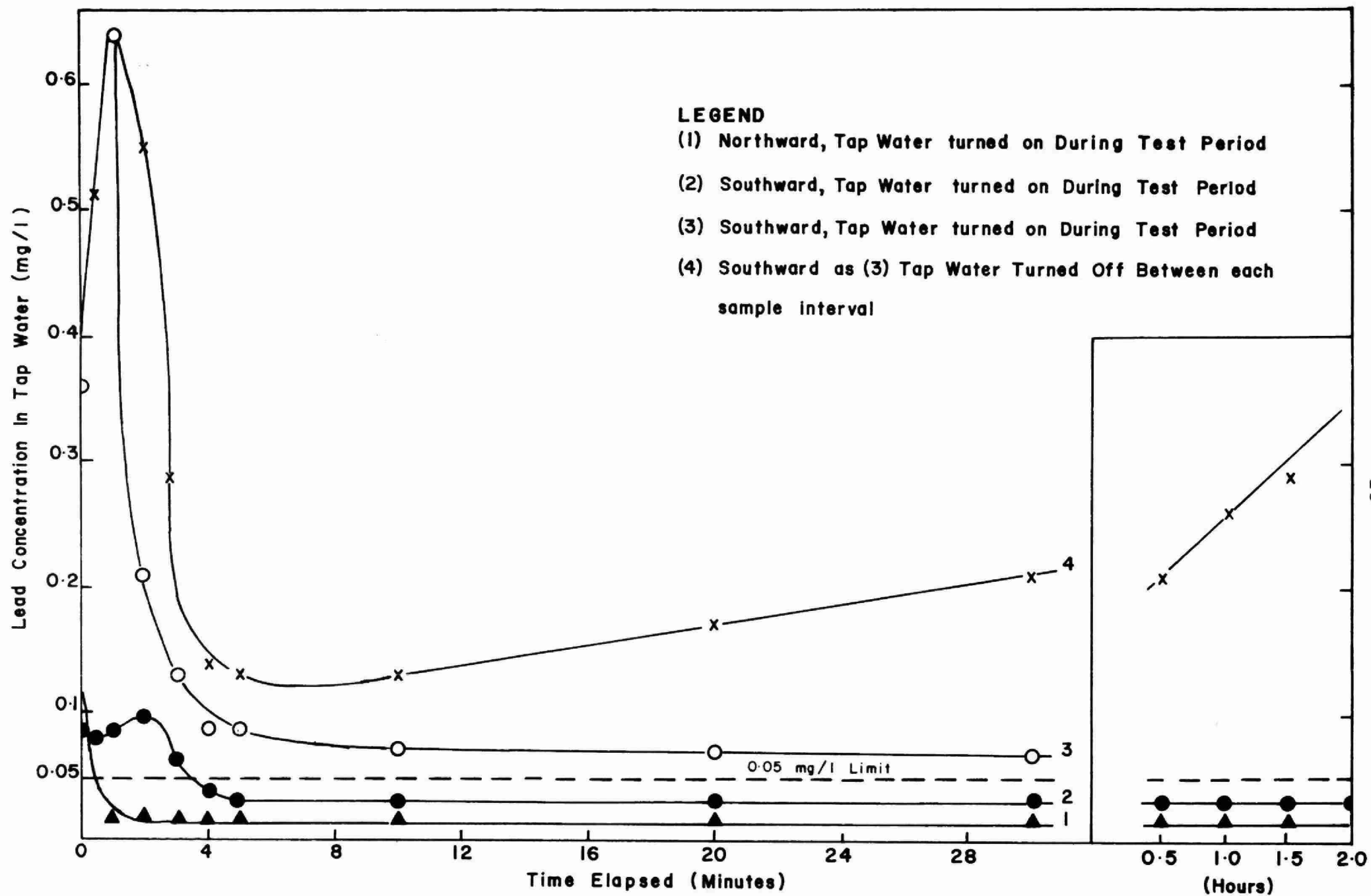


Figure 1 Lead Levels Versus Time Elapsed Since Tap Turned On

approximately 0.004 mg/l/min within the experimental range of 20 minutes (line 4). As the shut-down interval is raised to 30 minutes, the lead concentration in water continues to increase but at a slower rate of approximately 0.002 mg/l/min.

(2) Lead Levels of Water from Hot Water Tanks

As shown in Table VIII, the sample collected from the hot water tank at 436 South Norah Street showed a lead concentration of 0.063 mg/l slightly in excess of the permissible limit but slightly less than 0.070 mg/l, the value obtained from the cold water lines during the 30 minute flow-through test (Table VII, Sample Set #3). These results indicate that the hot water tank at 436 South Norah Street did not contribute anymore lead into the water than it already had received from the lead pipe connections. However, as shown in Phase I Study, Table III, the hot water at 1413 Moodie Street was 1.7 times higher in lead than the cold water. Obviously more lead had dissolved in passing through the hot water tank. The source of lead could be from the particulate material found in the water from this residence which could accumulate in the hot water tank and be dissolved at the elevated temperature.

An old hot water tank that had been in service for 12 years, and which was being replaced by Thunder Bay Hydro, was examined. After the tank had been drained and disconnected, an opening was made in the side and the contents examined. Little scale build-up was observed on

*increase probably due to hot water use
- taking in water with high lead levels
that had been sitting in the service line.*

the sides, but a considerable amount of debris had accumulated at the bottom of the tank. This debris was collected and after filtration at the Laboratory, an analysis was performed on both the filtered material and the water or filtrate. The results are reported in Table VIII, and indicate that there was a minor accumulation of lead in the hot water tank. Since this tank had been taken out of service, no hot water from this tank could be taken for lead analysis. Nevertheless, the filtered water from the sediment from the tank showed a high value of 1.03 mg/l, which logically indicated that water, on passing through the tank, could pick up more lead from this sediment.

TABLE VIII

Lead Levels in Water and Metallic Composition of Sediment from Hot Water Tanks.

Sample	Lead (mg/l)	% Composition
Hot Water Tank in Service (436 S. Norah St.)	0.063	
Hot Water Tank out of Service (350 N. Syndicate Ave.)		
(a) Filtered Water	1.03	
(b) Sediment		1.40 % lead 2.65 % copper 4.27 % iron 0.56 % zinc

(3) Chemical Treatment to Reduce Lead Uptake

This study undertaken by the Ministry Laboratory personnel was to determine the effectiveness of chemically treating the water supply to reduce the lead uptake capacity. The chemicals examined were sodium hydroxide, calcium hydroxide and sodium carbonate. It was found that an addition of any one of these chemicals to the South Ward water resulted in a reduction of the lead uptake which varied with the pH change but not with the type of chemicals. The amounts of each chemical required to raise the pH of the water to 7.5 are 3.5 mg/l for sodium hydroxide, 3.0 mg/l for calcium hydroxide and 9.3 mg/l for sodium carbonate. When the South Ward water was treated to a pH of 8.0 with any of the three chemicals the lead uptake capacity was approximately the same as that for the North Ward water.

With the chemical concentration ranges examined in this study, the pH achieved due to chemical addition was unstable and gradually decreased, thereby reducing the effectiveness of the chemical treatment for minimizing lead uptake. Typically, a sample of South Ward water treated to a pH of 8.0 reduced to 6.9 within five hours in the absence of air (similar condition occurs in the water distribution system). This phenomenon, which was not detected for the North Ward water, was consistently observed either in the presence or absence of air for both the chemically treated and untreated South Ward water.

Free chlorine coupled with the poor buffering capacity of the South Ward water was suspected to be the major cause for the unstable pH. Higher chemical dosages with their inherent higher buffering capacity could overcome the instability. Thus, the chemical treatment of the water supply to reduce the lead uptake capacity requires more careful study to determine the most effective chemicals and optimum chemical dosage to be used.

PERMISSIBLE LEAD LEVEL

Before providing an overall discussion of the above Ministry results, a brief explanation of the rationale behind using 0.05 mg/l for the rejection limit of a water supply should be mentioned. It has been determined that total intake lead levels from all sources should not exceed 0.6 mg. per day.⁽¹⁾ This includes such sources as food, air, tobacco smoke, as well as from water and other beverages.⁽²⁾ Since the daily intake of lead from food sources was estimated to be 0.3 mg/l⁽²⁾, a level of 0.05 mg/l was set as the safe limit for drinking water supplies. This 0.05 figure presumes a 2 litre daily water intake per person ($2 \times 0.05 = 0.10$ mg per day) and allows some flexibility of rates from other sources while still keeping within the maximum safe range of 0.6 mg total daily intake.

(1) EPA.R3.73.033. March, 1973 - Ecological Research Series, Water Quality Criteria, 1972.

(2) The Resources Agency of California, State Water Quality Control Board, Pub. 3A 2nd Ed. Water Quality Criteria.

OVERALL DISCUSSION

From the data presented, various observations can readily be noted. First, the lead concentrations in the raw water are insignificant when compared to the maximum permissible 0.05 mg/l. Also, those residences serviced by copper service connections had lead concentrations that were well below this level. In the case of homes serviced by lead connections, all had elevated lead concentrations. However, the lead concentrations found in the North Ward services were below the maximum permissible limit except when prolonged contact time of water with lead pipe was experienced. In the South Ward generally the lead levels were found to be in excess of the maximum permissible of 0.05 mg/l.

An explanation for the higher levels found in the South Ward is that Loch Lomond water has an alkalinity (20 mg/l as CaCO_3) approximately 50% of that in Lake Superior and hence a much lower buffering capability than that of the North Ward water. In other words the Loch Lomond water is much more aggressive than the Lake Superior water and reacts much more easily with the lead piping resulting in more lead dissolving into the water. By comparing the average values of lead concentrations in the samples in homes from both Wards using lead services, it can be seen that the lead uptake rate of the North Ward water is approximately 32% of the South Ward Water.

As it was shown before, the longer the exposure time to the lead service connection, the higher would be the lead concentration in the water. A maximum value in excess of 0.6 mg/l had been recorded in this study. Therefore, as long as a house is served by a lead connection, the water, normally consumed in a day, will contain some lead and the concentration could exceed the permissible limit especially in the South Ward as was evident in Tables III & V. By flushing the service connection to clear the water in the pipe, the lead level will reduce but for some cases, the concentration may still remain higher than the 0.05 mg/l permissible limit.

Since lead levels higher than the permissible limit have been noticed even when the tap water is kept running at 0.5 gal/min, some action should be taken to remedy the problem. Chemical treatment is probably the quickest solution although it may have some noticeable affect on the present residential, commercial and industrial users. Gradual replacement of lead connections with non-leaded ones will also eliminate the lead problem in a reasonable length of time. However, this action differs from the chemical treatment in that it will not solve the other corrosion problems which may exist due to the aggressive nature of the water.

CONCLUSIONS

Based on the information collected, the following conclusions have been made:

1. Total lead levels in excess of the 0.05 mg/l permissible criteria have been found in the North and South Wards.
2. The level of lead found directly relates to the lead service connection and to the aggressiveness of the water from Lake Superior and Loch Lomond.
3. The lead uptake rate of Lake Superior water was found to be only approximately 32% of Loch Lomond water and the lead levels in the North Ward were found equal or less than 0.05 mg/l, except when the water remained in the lead pipe over a long period of time.
4. The level of lead in the water increased directly with the resident time in the lead connection until a maximum level (≥ 0.64 mg/l) was reached.

RECOMMENDATIONS

In formulating recommendations that would lead to a reduction of lead levels in the City drinking water, it became readily apparent that some of the recommendations presented would be of a short term basis, while others would take longer to implement. Therefore, the recommendations presented below were divided into three categories, immediate, short term and long term.

Immediate:

The City should take immediate steps to notify all affected consumers, i.e. those on leaded connections, that they should flush their service connections by allowing their cold water tap to run at a high flow rate to drain about 3 gallons of water, when obtaining water for consumptive purposes.

Short Term:

The two recommendations presented below are alternatives which the City could complete in a reasonable length of time to alleviate the problem especially in the South Ward where the water is more aggressive.

1. Replacement of the leaded service connections with the non-leaded ones, which was estimated to cost approximately \$2,000,000.
2. Chemically treat the water to reduce its aggressiveness. This was estimated to cost approximately \$38,000 a year. This recommendation is par-

ticularly favoured as it will resolve corrosion problems in addition to reducing lead uptake and is likely to be the most economical of the two short term solutions suggested.

Long Term:

A long term solution to this problem could be the provision of completely treated water to all areas of Thunder Bay from one source. The City has already taken a step in this direction by retaining a consulting firm to do pilot treatability studies on the North Ward water supply. The consultants should also be instructed to study the requirements for servicing the entire City from this supply in the future.

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